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DEMONSTRATION MODEL SYSTEM. VOLUME IV. SLIDE-RULE MODEL SYSTEM --ETC(U)
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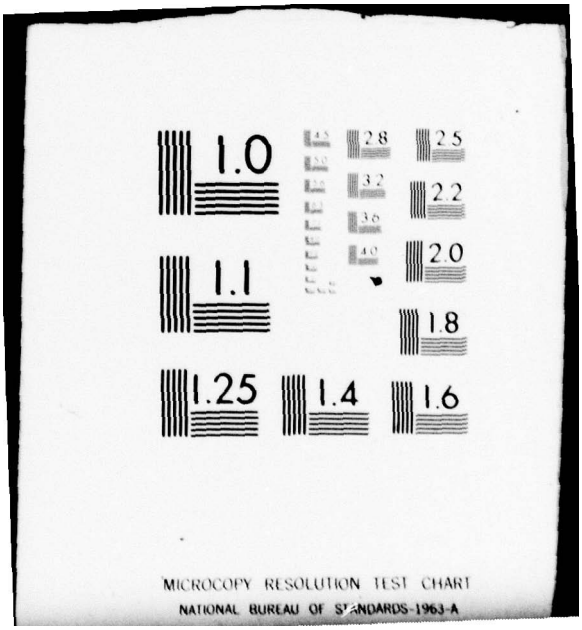
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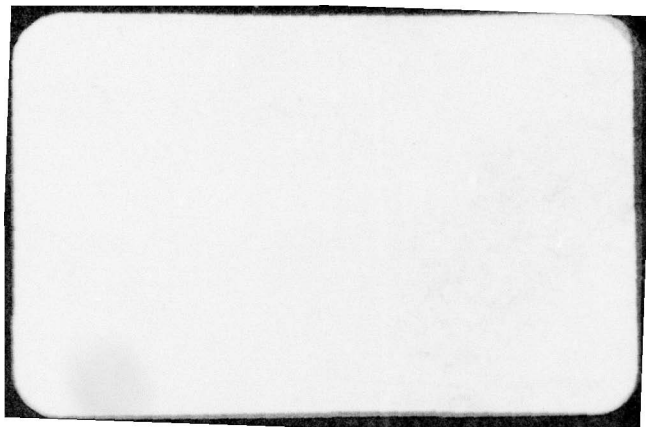

theassessmentgroup

710 Wilshire Boulevard, Suite 301
Santa Monica, California 90401
213/394-6778

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by

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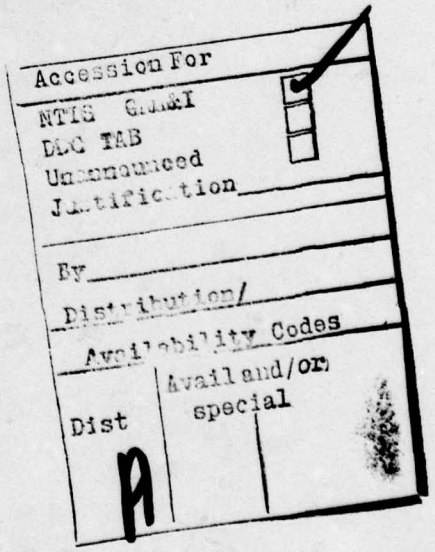


1.0 INTRODUCTION

The Slide-Rule Life Cycle Cost Model System (SRS) has been designed as an aid to system, subsystem and assembly designers in making cost estimates and trade-offs early in the design process. At this stage it is still possible for cost analysis to influence design - system cost has not yet been "locked in" due to the lack of flexibility in system configuration which occurs in the later phases of design.

The SRS consists of four linked programs implemented on a Texas Instruments TI-59 programmable calculator coupled to a TI PC-100A printer. Each program is appropriate to a different design phase and aggregation level. The first estimates the life cycle costs of a system by making simplifying assumptions about its subelements; the second is used for the design of a single Lowest Removable Assembly (LRA); the third estimates system or subsystem costs by aggregating the costs of its subelements, computed in the second program; the fourth is a specialized program used to compute the achieved system confidence level against a stock-out of spare parts.

The running times of all programs are less than one minute. This, combined with the "no-cost" running feature of the program, makes the SRS an excellent design tool for experimenting with design/cost trade-offs early and often in the design process.

Sections 2 through 5 describe each program, including the cost equations, input variable definitions, and flow charts, where

appropriate. Annotated program listings are provided in four Appendices.

2.0 THE TOP-DOWN MODEL

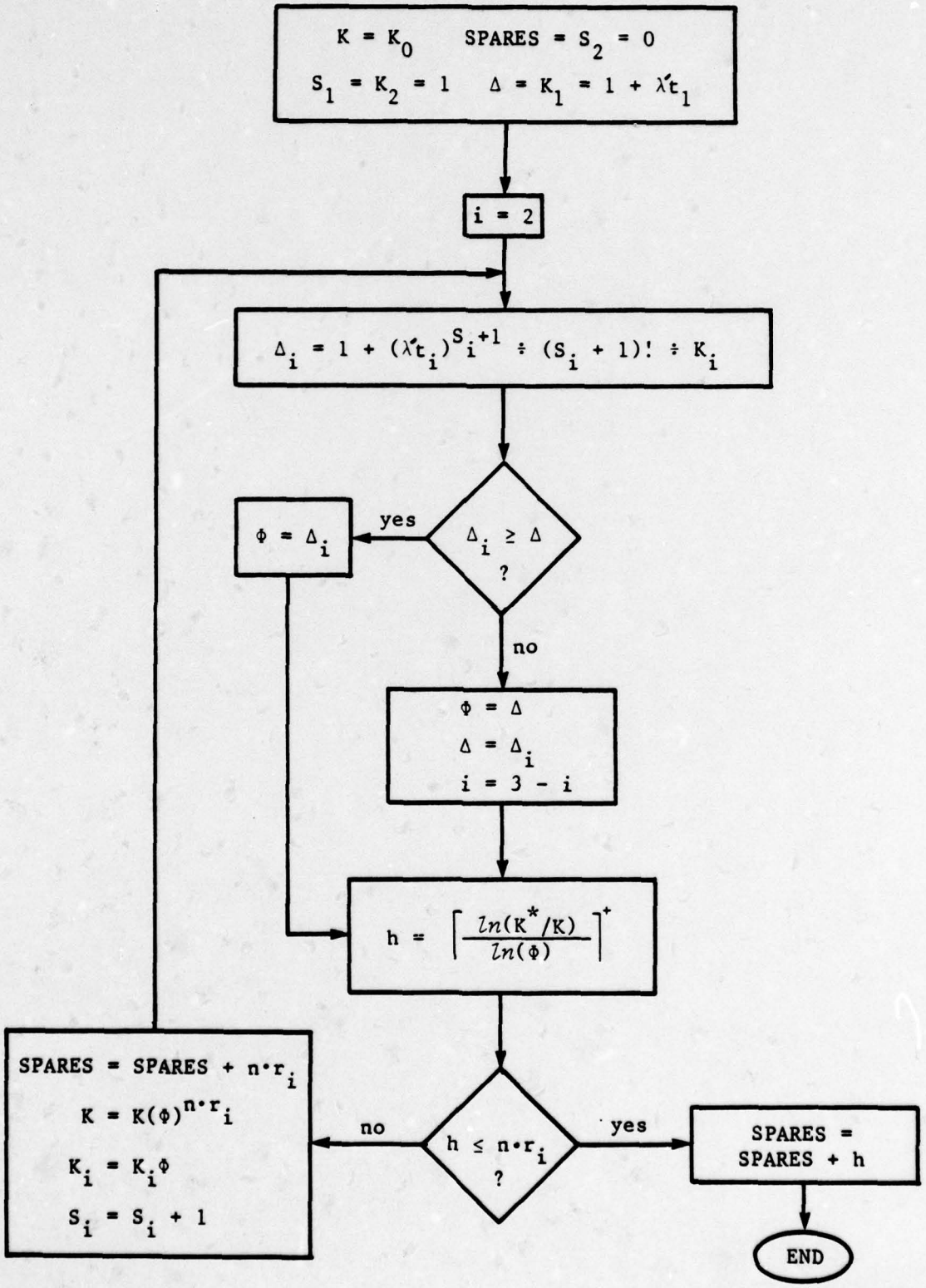
The Top-Down Model (TDM) computes total life-cycle cost as the sum of nine cost categories: maintenance personnel compensation, maintenance training, operator compensation, operator training, production and spares, support and test equipment, repair costs, item entry and management, and documentation. The first seven cost categories are computed for each ship and then multiplied by the number of ships on which the system is to be deployed.

The program requires as input 27 data elements which characterize the design of a system. An additional 21 constants, describing the operating environment of the system, are incorporated into the program code. Design/cost trade-offs are accomplished by altering the input data elements and observing the effect on life-cycle cost.

Some of the main features of the cost model are: a sophisticated routine for determining on-board spares for repairable items (a flow chart of this routine is presented in Figure 1, a learning curve routine which adjusts the estimated unit production cost of the system based on the total number of systems and spares procured, discounting to present value of recurring costs (this option can be suppressed, if desired), and a new approach to manpower costing based on the concept of opportunity cost.

Program operation is simple and quick. Data elements are input to the model by storing them in appropriate memory registers. Execution is initiated by pressing a single button. Output consists of each of the cost categories and total life-cycle cost. To further

Figure 1 TDM Spares Algorithm



simplify the output, the printing of any or all of the cost categories can be suppressed by setting an appropriate flag. Turn-around time for cost results is approximately one minute.

The next sections summarize the TDM cost equations and present detailed definitions of the input variables.

TDM Cost Equation Summary

System failure rate: $\lambda = Q \cdot AHR/MTBF$

LRA peak failure rate: $\lambda' = s\lambda/n$

On-board spares: $S = SPARES/n'$

Demand at depot: $\mu = \lambda' \cdot N/d \cdot DRT$

Depot spares: $B = \lceil \mu + Z_b \sqrt{\mu} \rceil \cdot d \cdot r_2 \cdot n/n'$

Replenishment spares: $S' = \lambda \cdot D \cdot h \left[1+(r_1+r_2)(1-COND)\right]/n'$

Adjusted unit production cost:
$$UC = UC_\ell \left[\frac{N(Q+S+S')+B}{\ell} \right]^{\log RRATE/\log 2}$$

Life cycle discount factor:
$$L = \begin{cases} \dfrac{(1+\rho)^{LC}-1}{\rho(1+\rho)^{LC}} & \rho \neq 0 \\ LC & \rho = 0 \end{cases}$$

Peak operator demand: $M_o' = s \cdot Q \cdot \theta \cdot PHR/WH_o$

Peak maintenance manpower demand: $M_m' = (s\lambda MTTRS(1+\tilde{M}r_1)+Q \cdot SM)/(U \cdot WH_m)$

Maintenance "C" training course cost: $TC_m = TS_m(1+\tilde{T}nr_1)$

TDM Cost Equation Summary (cont'd)

Maintenance wage: $C_1 = \text{Wage}(M_m', AN_m, BN_m)$

Maintenance training: $C_2 = \text{Trn}(M_m', AN, TC_m)$

Operator wage: $C_3 = \text{Wage}(M_o', AN_o, BN_o)$

Operator training: $C_4 = \text{Trn}(M_o', AN_o, TC_o)$

Production and spares: $C_5 = [(Q+S+S'L)\cdot N + B]UC$

Support and test equipment: $C_6 = STE(1+SGM(r_1)\tilde{S})(1+mL)\cdot N$

Repair: $C_7 = \lambda\cdot D\cdot h(r_1 RP + r_2 COD)\cdot N$

Item entry and management: $C_8 = IECn + IMC\cdot L\cdot n\,[\,1 + PP(r_1 + r_2)]$

Technical data: $C_9 = DOC(1+\tilde{D}r_1 n)$

Life cycle cost: $LCC = \sum_{j=1}^{9} C_j$

TDM Cost Equation Summary (cont'd)

Personnel Costs:

$$A(M') = \lceil M' - \min(M', AN) \rceil$$

$$\text{Wage}(M', AN, BN) = \left[M \cdot BG + A(M')(BN-BG)\right] \cdot L \cdot N,$$

$$\text{Trn}(M', AN, TC) = \left[\lceil M' \rceil \cdot TC + A(M')TA\right](1+TOR \cdot L) \cdot N,$$

TDM Input Variable Summary

r_1	The fraction of LRA types in the system coded local repair.
r_2	The fraction of LRA types in the system coded depot repair. $1-r_1-r_2$ is the fraction of LRA types coded discard on failure.
LRT (weeks)	The average time for an item coded local repair to be returned to ready for issue status.
D (weeks)	The length of the deployment period.
n'	The total number of LRA's in the system.
n	The number of LRA types in the system. (Each LRA appears an average of n'/n times in the system.) Note: because of logic of the sparing algorithm, the smaller the value of n, the longer the program running time.
s	The ratio of peak operating hours to average operating hours. The input s can be seen as a policy variable which determines the ability of the supply system to withstand periods of increased activity.
N	The number of ships on which the system is to be deployed.
AN_m	The size of the pool of available, trained maintenance personnel on-board ship.
BN_o ($'000)	Annual billet cost for trained personnel used to maintain the system. Value taken from the Billet Cost Model (BCM). The undiscounted value should be used.
TC_m ($'000)	System repair training course cost for maintenance personnel. Does not include the course cost of training to repair individual LRA's coded local repair.
AN_o	Same as AN_m for operators.
BN_o	Same as Bn_m for operators.
TC_o ($'000)	Operator training course cost.

TDM Input Variable Summary (cont'd)

LC	(years)	Length of system life cycle.
MTBF	(hours)	Mean time between failure of the system. The value used should be adjusted for fixed field operations.
UC_ℓ	($'000)	The estimated unit production cost of the system assuming that ℓ units are produced.
ℓ		The lot size used to define UC_ℓ.
Q		The number of systems deployed per ship.
AHR	(hr./wk.)	The average weekly operating hours of the system per operating week.
MTTRS	(manhour)	The number of manhours required to restore the system to operational status after the failure of an LRA.
SM	(man-hr./wk.)	The weekly scheduled maintenance requirement. Includes all facility and preventative maintenance.
θ		The number of operators required to man the system when fully operational.
STE	($'000)	Purchase cost of all support and test equipment necessary for the repair of the system. Does not include common or specific STE used for the repair of failed LRA's.
COD	($'000)	The average cost of a repair at a contractor operated depot repair facility. COD includes the round-trip transportation cost of the item in addition to all other costs, direct and indirect, of a repair.
RP	($'000)	The average repair parts material cost required for the local repair of an LRA.
DOC	($'000)	The cost of documentation for system operation and repair. Does not include the documentation cost for the repair of individual LRA's.

TDM Variable Summary (Code Constants)*

BG ($'000)	The undiscounted annual billet cost for general labor personnel. Value taken from the BCM.
TA ($'000)	Average cost of "A" school training for operators and maintenance personnel.
TOR ($'000)	Average annual personnel attrition rate for military personnel.**
K*	Desired system level confidence level against stock-out of on-board spares.
DRT/d (weeks)	The average time for an item sent to a repair depot to be returned to the holding depot stock-pile divided by the number of holding depots.
Z_b	The number of standard deviations from the mean required to achieve the desired confidence level against stock-out at the depot.
d	The number of holding depots at which failed LRA's from ships are replaced by ready-to-issue LRA's.
h	The number of deployments in a year.
1-COND	1 minus the ratio of failed LRA's coded repair which cannot be repaired to the total number of LRA's coded repair. COND is an average value for local and depot repair facilities.**
log RRATE/log 2	The learning curve cost reduction coefficient. Equal to the log of the reduction rate divided by log 2.
ρ	Annual discount rate.**
$\tilde{M}$	The ratio of the mean time to repair a failed LRA coded local repair to the mean time to remove and replace the LRA (MTTRS, defined above).

*Code constants are input variables, describing the operating environment in which the system is placed, which have been incorporated into the code of the cost model programs.

**Default value taken from "Naval Air Systems Command Avionics Level of Repair Model, Mod III Default Data Guide, 1 July 1977," NWESA, Washington Naval Yard.

TDM Variable Summary (Code Constants)* (cont'd)

$WH_m \cdot U$ (hr./wk.)	Available weekly work hours at sea for maintenance personnel (non-watchstanders), times the utilization rate, which serves to decrease available work time by accounting for delays arising from fatigue, environmental effects, personal needs, unavoidable interruptions, in addition to maintenance put-away, administrative, and overhead time.***
$\tilde{T}$	The ratio of the average training course cost specific to the repair of an individual LRA coded local repair to the system repairs training course cost (TC_m, defined above).
WH_o	Available weekly work hours for operators, that is, total available hours weekly (168) minus sleep, messing, personal needs and free time.***
$\tilde{S}$	The ratio of purchase cost of the common support and test equipment which would be needed if any of the LRA's in the system are coded local repairs to system repair STE (STE, defined above).
m	Annual support of support equipment maintenance factor.**
IEC ($'000)	Cost of entering a new item into the Naval Stock System (NSN) inventory.**
IMC ($'000)	Annually recurring cost of retaining an item in the NSN.**
PP	The average number of unique new components in each LRA type; nPP gives the total number of new components in the system.
$\tilde{D}$	The ratio of the cost of specific documentation required for an individual LRA coded local repair to the cost of system repair documentation (DOC, defined above).

**Default value taken from "Naval Air Systems Command Avionics Level of Repair Model, Mod III Default Data Guide, 1 July 1977," NWESA, Washington Naval Yard.

***Default value taken from OPNAV 10P-23, "Guide to the Preparation of Ship Manning Documents, Volume I: Policy Statement," OPNAV 10P-23 Washington, D.C., 1971.

3.0 The Lowest Removable Assembly Model

The Lowest Removable Assembly Model (LRAM) computes total life-cycle cost as the sum of seven cost categories: maintenance personnel wage, maintenance personnel training, production and spares, support and test equipment, repair, item entry and management, and documentation. The first five categories are multiplied by the number of ships on which the LRA is to be deployed.

The program requires as input 16 data elements which characterize the design of the LRA. An additional set of 21 variables are input to the model on an operating environment card provided by the system designer. This card also includes the printing op. codes for the program output labels. Design/cost trade-offs are accomplished by altering the input data element and observing the effect on life cycle cost.

Some of the main features of the model are: level of repair analysis capabilities which include local repair, depot repair and discard options, a sophisticated spares routine which automatically calculates the (near) optional mix of on-board and depot spares required to meet the LRA confidence level, complete manpower cost formulations for maintenance personnel, and full output labeling capabilities. As in the TDM, printing of individual cost categories can be suppressed by setting appropriate flags. Turn-around time for cost results is approximately forty seconds.

The next sections summarize the LRAM cost equations and present detailed definitions of input variables. Flow charts of model subroutine logic are presented in Figure 2.

Figure 2 LRAM Subroutine Flowcharts

Figure 2-A

S(t,K): Number of spares needed to meet confidence level K given demand lead time t.

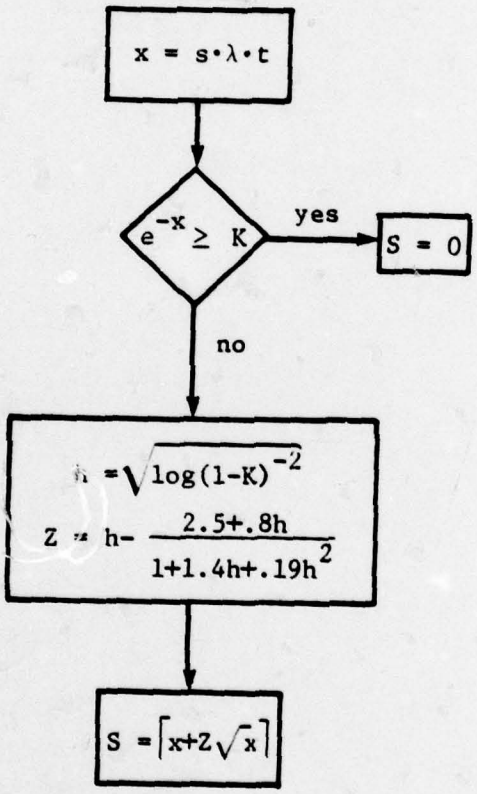
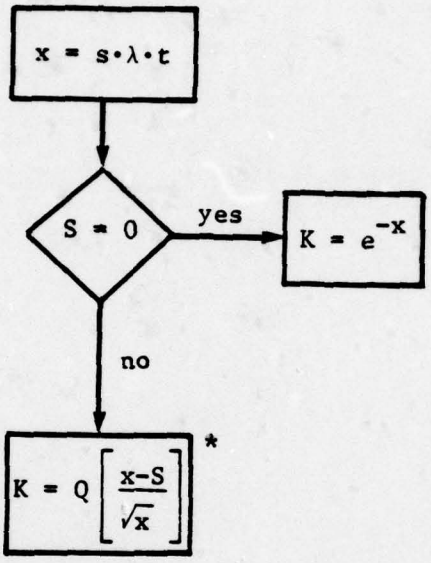


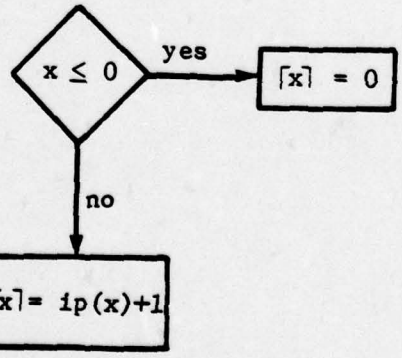
Figure 2 LRAM Subroutine Flowcharts (cont.)

Figure 2-B

K(t): Confidence level achieved with S spares and demand lead time λt.



$\lceil x \rceil$: Round-up to next higher integer.



*Q(x) is computed in a program contained in the master library module which comes with the TI-59 calculator.

LRAM Cost Equation Summary

LRA peak failure rate: $\lambda = sqQ\delta AHR/MTBF$

Lead time: $t = r_1 LRT + r_2 D$

On-board spares: $S = S(t,K)$

Depot confidence level: $b = \frac{K-K(XD)}{K(D)-K(XD)}$

Depot spares: $B = r_2 S(N/d \cdot DRT, b) \cdot d$

Replenishment spares: $S' = \lambda \cdot D \cdot h \; 1-(r_1 + r_2)(1-COND)$

Adjusted unit production cost: $UC = UC_\ell \left[\frac{N(q \cdot Q+S+S') + B}{\ell} \right]^{\log RRATE/\log 2}$

Maintenance manpower peak demand: $M_m' = s\lambda(MTPR + r_1 MTTR)/(U \cdot WH_m)$

"A" school training requirement: $A(M_m') = \left[M_m' - \min(M', AN_m) \right]$

Maintenance wage: $C_2 = \left[M_m'/s \cdot BG + A(M_m')(BN_m - Bg) \right] L \cdot N$

Maintenance training: $C_3 = \left[M_m' (TFI + r_1 TR) + A(M_m') TA_m \right] \cdot (1+TOR \cdot L) \cdot N$

Production and spares: $C_4 = \left[(q \cdot Q+S+S'L)N + B \right] UC$

LRAM Cost Equation Summary (cont'd)

Support and test equipment:

$$C_5 = (STE+r_1 STE_{rpr})(1+mL)\cdot N$$

Repair:

$$C_6 = \lambda D\cdot h\cdot L(r_1 UC/c+r_2 \cdot COD)\cdot N$$

Item entry and management:

$$C_7 = (IEC+IMC\cdot L)(1+(r_1+r_2)\bar{c})$$

Technical data:

$$C_8 = P_f + r_1 P_r$$

Life cycle cost:

$$LCC = \sum_{j=2}^{8} C_j$$

LRAM Input Variable Summary

q		Number of LRA appearances in the system as a whole.
δ		LRA duty cycle: the ratio of LRA to system operating hours.
MTBF	(hrs.)	LRA mean time between failure.
r_1		Level of Repair switch which is set equal to 1 if the LRA is coded local repair, otherwise it is set equal to zero.
r_2		Level of Repair switch which is set equal to 1 if the LRA is coded depot repair, otherwise it is set equal to zero. If $r_1 = r_2 = 0$ the LRA is coded discard on failure.
UC_ℓ	($'000)	Estimated unit cost of the LRA assuming a production lot size of ℓ.
MTTRS	(manhrs.)	The average manhours required to restore the system to operational status after a failure of the LRA. Equivalently, the mean time to fault isolate to, remove and replace the LRA upon failure.
MTTR	(manhrs.)	The average maintenance manhours needed to repair the LRA if it is coded local repair.
TFI	($'000)	The addition to the system level maintenance training course cost needed to train personnel to fault isolate to, remove and replace this particular LRA. (In other words, TFI > 0 only if this LRA would require special mention in the system repair training course.)
TR	($'000)	The course cost required to train personnel to repair the LRA locally.
STE	($'000)	The purchase cost of any additional system repair support and test equipment needed to fault isolate to, remove and replace this particular LRA.

LRAM Input Variable Summary

STE_{rpr}	($'000)	The purchase cost of all support and test equipment necessary to the local repair or maintenance of this particular LRA.
c		The number of components in the LRA. (Repair of the LRA consists of removing and replacing components.)
$\bar{c}$		The number of new components, unique to the LRA, which must be entered in the Naval inventory management system.
DOC	($'000)	The addition to the system repair documentation cost needed to document the fault isolation, removal and replacement of this LRA.
DOC_{rpr}	($'000)	The cost of documentation of the procedure to repair the LRA locally.

All other variables are as defined in the TDM, with three exceptions:

K	is the desired confidence level against stock-out for the LRA, K_i's for each LRA are assigned so that $\prod K_i = K^*$.
AN_m	is the available pool of trained maintenance personnel available to the LRA. $AN_{m,i}$'s are assigned so that $\sum AN_{m,i} = M$, the desired system level maintenance manpower requirement.
L	is the discounted life cycle computed in the TDM.

4.0 THE SYSTEM AGGREGATION MODEL

The System Aggregation Model (SAM) computes life cycle cost as the sum of the same nine cost categories as the TDM. The input of the program is the output of the LRAM for each LRA type used in the system, plus system level input data. Design trade-offs are accomplished by altering the number and type of LRA's used to build up the system.

One of the most powerful features of the SAM is that SAM program output can be input to the model. Thus, for example, the SAM can be used to aggregate LRA's into sybsystems, and then used again to aggregate these subsystems and systems. Mixed aggregation levels are possible; input to the SAM can consist partially of LRA's (LRAM output) and partially of subsystems (LRAM output preaggregated using the SAM). And, of course the multiple aggregation-level option is available.

Other features of the SAM include: automatic calculation of achieved system MTBF and MTTR, based on the MTBF's and MTTR's of the LRA's used in a given system configuration; manpower cost calculations based on aggregated personnel demand and training course requirements, and complete output labeling capabilities. As in the other models, intermediate cost outputs can be suppressed by setting appropriate flags. Program running time is approximately ten seconds per LRA input, plus an additional 20 seconds to compute and print system level costs.

The next sections present a summary of SAM cost equations and input variables.

SAM Cost Equation Summary

Aggregation Factor: $$R_i = \frac{q \cdot QIPA_i}{q_i}$$

Peak maintenance demand: $$M'_m = Q \cdot SM / U \cdot WH_m + \sum^{n} R_i M'_{m,i}$$

Maintenance training cost: $$TC_m = TS_m + \sum^{n} R_i TC_{m,i}$$

Operator training cost: $$TC_o = TS_o + \sum^{n} R_i TC_{o,i}$$

Peak operator demand: $$M'_o = s \cdot Q \cdot q \cdot \theta \cdot AHR / WH_o$$

Maintenance wage: $$C_1 = Wage(M'_m, AN_m, BN_m)$$

Maintenance training: $$C_2 = Trn(M'_m, AN_m, TC_m, TA_m)$$

Operator Wage: $$C_3 = Wage(M'_o, AN_o, BN_o)$$

Operator training: $$C_4 = Trn(M'_o, AN_o, TC_o, TA_o)$$

Hardware: $$C_5 = PT_{\ell}\left[\frac{N \cdot Q \cdot q}{\ell}\right]^{\log RRATE / \log 2} + \sum^{n} R_i HRDW_i$$

Support and test equipment: $$C_6 = STE_{sys}(1+mL)N + \sum^{n} R_i STE_i$$

Repair: $$C_7 = \sum^{n} R_i RPR_i$$

Item entry and management: $$C_8 = \sum^{n} R_i IEMC_i$$

SAM Cost Equation Summary (cont'd)

Technical Data:

$$C_9 = DOC_{sys} + \sum^{n} R_i DOC_i$$

Life cycle cost:

$$LCC = \sum_{j=1}^{9} C_j$$

System mean time to repair:

$$MTTR = \frac{\sum QIPA_i MTTR_i \cdot \lambda_i}{\sum QIPA_i \cdot \lambda_i}$$

System MTBF:

$$MTBF = \left[\sum^{n} \frac{QIPA_i}{MTBF_i} \right]^{-1}$$

SAM Input Variable Summary

q		The number of units in the system. If the SAM is being used at the system level, $q = 1$.
SM		Same as above. If the SAM is used at the subsystem level, refers to subsystem scheduled maintenance requirement.
AN_m		Same as above. If the SAM is used at the subsystem level, AN_m is assigned to the subsystem in the same manner as AN_m in the LRAM.
TA_m	($'000)	"A" school training course cost for maintenance personnel.
AN_o		Same as AN_m, above, but refers to operators.
TA_o	($'000)	"A" school training course cost for operators.
PT_ℓ	($'000)	The estimated assembly, or put-together, cost of the system. Equivalently, the total production cost of the system less the production costs of all sub-elements.

All other variables are as defined above.

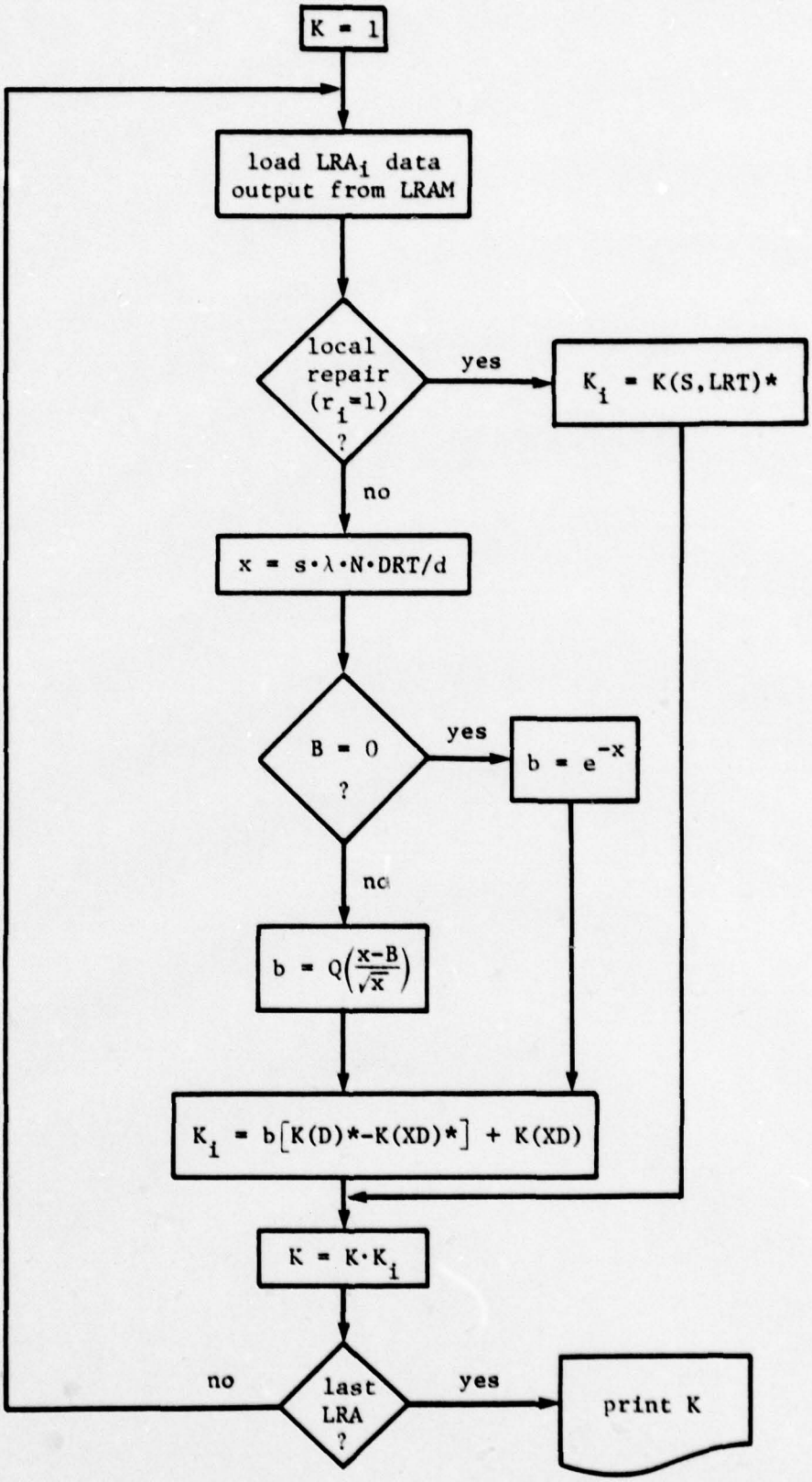
5.0 The System Confidence Model

The System Confidence Model (SCM) is a specialized program which determines the achieved confidence level against stockout for each LRA type and for the system as a whole.

SCM input consists of LRAM output for each LRA type plus a system operating environment card. The program multiplies LRA confidence levels into an accumulation register containing the current system confidence level. Once all LRA's have been read into the SCM, this register, containing the achieved system confidence level, is printed.

A flow chart of SCM logic is presented in Figure 3. All input variables to the SCM are as defined above.

Figure 3 SCM Program Logic



*These values were calculated and stored as part of the sparing algorithm in the LRAM.

APPENDICES:

ANNOTATED PROGRAM LISTINGS FOR

A: TOP-DOWN MODEL

B: LOWEST REMOVABLE ASSEMBLY MODEL

C: SYSTEM AGGREGATION MODEL

D: SYSTEM CONFIDENCE MODEL

APPENDIX A:

TOP-DOWN MODEL

PROGRAM LISTING

INDIRECT RECALL

```
000   76 LBL
001   43 RCL   Recalls values
002   73 RC*   used in SPARES
003   00  00   and PERSONNEL
004   69 OP    routines
005   20  20
006   92 RTN
```

$\lceil x \rceil$

```
007   76 LBL
008   59 INT
009   95  =
010   32 X:T
011   00  0
012   77  GE   ⌈x⌉ = { 0  x≤0
013   00  00         { ip(x)+1  x>0
014   20  20
015   32 X:T
016   59 INT
017   85  +
018   01  1
019   95  =
020   92 RTN
```

PRINT and SUM to LCC

```
021   65  ×
022   43 RCL
023   13  13
024   95  =    LCC = LCC + N·Cj
025   44 SUM   if j≤7 (enter at 021)
026   37  37
027   69 OP
028   21  21   LCC = LCC + Cj
029   87 IFF   if j≥8 (enter at 024)
030   40 IND
031   01  01
032   00  00
033   35  35
034   99 PRT
035   92 RTN
```

SUBROUTINE PERSONNEL

```
036   43 RCL
037   38  38
038   32 X:T
039   43 RCL
040   38  38
041   75  -
042   71 SBR
043   43 RCL
044   32 INV
045   77  GE
046   00  00
047   49  49
048   32 X:T
049   71 SBR
050   59 INT
051   42 STO   A(M',AN) = ⌈M' - min(M',AN)⌉
052   04  04
```

Wage = (M'16·BG + A(BN-BG))·L·N

```
053   34  +/-
054   85  +
055   43 RCL
056   38  38
057   55  ÷
058   43 RCL
059   12  12
060   95  =
061   65  ×
062   01  1
063   00  0   ← BG
064   93  .
065   05  5
066   85  +
067   71 SBR
068   43 RCL
069   65  ×
070   43 RCL
071   04  04
072   95  =
073   65  ×
074   43 RCL
075   03  03
076   71 SBR   print Wage
077   00  00
078   21  21
```

$T_{rn} = (TM \cdot TC + A \cdot TA)(1 + TOR \cdot L) \cdot N$

```
079   43 RCL
080   38  38
081   71 SBR
082   59 INT
083   65  ×
084   71 SBR
085   43 RCL
086   85  +
087   43 RCL
088   04  04
089   65  ×
090   01  1   ← TA
091   00  0
092   93  .
093   00  0
094   95  =
095   65  ×
096   53  (
097   01  1
098   85  +
099   93  .   ← TOR
100   04  4
101   05  5
102   65  ×
103   43 RCL
104   03  03
105   54  )
106   71 SBR
107   00  00  Print Trn
108   21  21
109   92 RTN
```

end of subroutine PERSONNEL

BEGIN EXECUTION

```
110   43 RCL
111   11  11
112   43 RCL
113   24  24
114   65  ×
115   43 RCL
116   25  25
117   55  ÷
118   43 RCL
119   21  21
120   95  =
121   42 STO   λ = AHR · Q/MTBF
122   37  37
123   65  ×
124   43 RCL
125   12  12
126   55  ÷
127   43 RCL
128   11  11
129   95  =
130   42 STO   λ' = sλ/n
131   36  36
132   65  ×
133   43 RCL
134   11  11
135   65  ×
136   53  (
137   43 RCL
138   02  02
139   65  ×
140   43 RCL
141   05  05
142   85  +
143   43 RCL
144   06  06
145   65  ×
146   43 RCL
147   09  09
148   54  )
149   95  =
150   94 +/-
151   22 INV
152   23 LNX
153   42 STO   k_b = e^{-[sλ(r_1 LAT + r_2 D)]}
154   35  35
```

```
155   00   0
156   42 STO
157   34   34
158   42 STO   SPARES: S_3 = 0
159   07   07
160   01   1
161   42 STO
162   08   08
163   42 STO   S_1 = K_2 = 1
164   03   03
165   85   +
166   43 RCL
167   36   36
168   65   ×
169   43 RCL
170   02   02
171   95   =
172   42 STO
173   04   04
174   42 STO
175   38   38   Δ = k_1 = 1 + λ't_1
176   06   6
177   42 STO   i = 2   0 is ind reg for i. r_2 is stored in reg. 6
178   00   00
```

$$\Delta_i = 1 + \frac{(\lambda' t_i)^{S_i+1}}{(S_i+1)!\ K_i}$$

```
179   01   1
180   85   +
181   53   (
182   43 RCL
183   36   36
184   65   ×
185   71 SBR
186   43 RCL
187   54   )
188   45 YX
189   53   (
190   71 SBR
191   43 RCL
192   85   +
193   01   1
194   54   )
195   42 STO
196   01   01
```

```
197   55   ÷
198   53   (
199   01   1
200   65   ×
201   43 RCL
202   01   01
203   97 DSZ
204   01   01
205   02   02
206   00   00
207   54   )
208   55   ÷
209   71 SBR
210   43 RCL
211   95   =
212   32 X:T
```

} computes $S_i!$

```
213   43 RCL
214   38   38
215   22 INV   Δ < Δ_i ?
216   77   GE
217   02   02
218   30   30   no
219   32 X:T
220   42 STO   Δ = Δ_i
221   38   38
222   01   1
223   04   4
224   75   -
225   43 RCL
226   00   00
227   95   =
228   42 STO   i = 3 - i
229   00   00
230   93   .   ← K*
231   09   9
232   05   5
233   55   ÷
234   43 RCL
235   35   35
236   95   =
237   23 LNX
238   55   ÷
239   32 X:T
240   42 STO   hold φ in R_1
241   01   01
242   23 LNX
243   71 SBR   h = ⌈ ln(K*/K) / ln φ ⌉^+
244   59 INT
245   32 X:T   hold h in t
```

$\bar{S} = (B/N + S)\ln' + Q$

```
246   73 RC*
247   00   00
248   65   ×
249   43 RCL   if nr_i > h
250   11   11  then end
251   95   =
252   77   GE   otherwise
253   02   02
254   79   79
255   44 SUM
256   34   34   SPARES = SPARES + nr_i
257   48 EXC
258   01   01
259   69 OP
260   30   30
261   64 PD*
262   00   00   K_i = φK_i
263   45 Y^x
264   43 RCL
265   01   01
266   95   =
267   49 PRD
268   35   35   K = kφ^nr_i
269   69 OP
270   30   30
271   01   1
272   74 SM*
273   00   00   S_i = S_i + 1
274   69 OP
275   30   30
276   61 GTO
277   01   01
278   79   79
279   32 X:T   final spares buy
280   44 SUM   SPARES = SPARES + h
281   34   34
```

```
282   43 RCL
283   34   34
284   65   ×
285   43 RCL
286   13   13
287   65   ×
288   01   1   ← DRT/d
289   03   3
290   95   =
291   42 STO
292   01   01  μ = λ'N·DRT/d
293   34 FX
294   65   ×
295   01   1   ← Z_b
296   93   .
297   06   6
298   05   5
299   85   +
300   43 RCL
301   01   01
302   71 SBR
303   59 INT
304   65   ×
305   02   2   ← d
306   65   ×
307   43 RCL
308   09   09
309   65   ×
310   43 RCL
311   11   11
312   55   ÷
313   43 RCL  B = [μ + Z_b√μ]·d·c_2·n/N
314   13   13
315   85   +
316   43 RCL
317   34   34
318   95   =
319   55   ÷
320   43 RCL
321   10   10
322   85   +
323   43 RCL
324   24   24
325   95   =
326   42 STO
327   34   34
```

$s' = \bar{\lambda}[1-(r_1+r_2)(1-COND)]/h'$

```
328   43 RCL
329   37   37
330   65   ×
331   43 RCL
332   06   06
333   65   ×
334   02   2   ← h
335   95   =
336   42 STO
337   36   36   λ̄ = λ·D·h
338   55   ÷
339   43 RCL
340   10   10
341   65   ×
342   53   (
343   01   1
344   75   -
345   53   (
346   43 RCL
347   05   05
348   85   +
349   43 RCL
350   09   09
351   54   )
352   42 STO
353   39   39
354   65   ×
355   93   .   ← 1-COND
356   09   9
357   08   8
358   54   )
359   95   =
360   42 STO
361   07   07   s'
```

$$UC = UC_e\left[\frac{N(s'+\xi)}{e}\right]^{\log RRATE/\log 2}$$

```
362   35   +
363   43 RCL
364   34   34
365   95   =
366   65   ×
367   43 RCL
368   13   13
369   55   ÷
370   43 RCL
371   23   23
372   95   =
```

```
373   45 YX
374   93   .   ← log RRATE/log 2
375   01   1
376   05   5
377   94 +/-
378   65   ×
379   43 RCL
380   22   22
381   95   =
382   42 STO
383   08   08
```

$$L = \frac{(1+p)^{LC}-1}{p(1+p)^{LC}}$$

```
384   ??   ?
385   01   1   ← p
386   00   0
387   42 STO
388   03   03
389   85   +
390   01   1
391   95   =
392   45 YX
393   43 RCL
394   20   20
395   87 IFF   if flag D is
396   00   00   set then L=LC
397   04   04
398   16   16
399   75   -
400   01   1
401   95   =
402   55   ÷
403   43 RCL
404   03   03
405   55   ÷
406   53   (
407   01   1
408   85   +
409   43 RCL
410   03   03
411   54   )
412   45 YX
413   43 RCL
414   20   20
415   95   =
416   42 STO
417   03   03   L
```

$M'_m = [s\lambda MTTRS(1+\tilde{M}r_1) + Q\cdot SM]/(U\cdot WH_m)$

```
418  43 RCL
419  12  12
420  65  ×
421  43 RCL
422  37  37
423  65  ×
424  43 RCL
425  26  26
426  65  ×
427  53  (
428  01  1
429  85  +
430  01  1   ← M̃
431  93  .
432  00  0
433  65  ×
434  43 RCL
435  05  05
436  54  )
437  85  +
438  43 RCL
439  24  24
440  65  ×
441  43 RCL
442  27  27
443  95  =
444  55  ÷
445  05  5   ← U·WHm
446  03  3
447  95  =
448  42 STO
449  38  38
```

$TC_m = TS(1+\bar{r}_{1,n})$

```
450  43 RCL
451  28  28
452  65  ×
453  53  (
454  01  1
455  85  +
456  01  1   ← r̄
457  93  .
458  00  0
459  65  ×
460  43 RCL
461  05  05
462  65  ×
463  43 RCL
464  11  11
465  54  )
466  95  =
467  42 STO
468  16  16
```

initialize

```
469  01  1
470  04  4
471  42 STO   indirect register for
472  00  00   o and m subscripted
473  00  0    variables
474  42 STO
475  37  37   LCC > 0
476  42 STO   indirect register for
477  01  01   print/no print flag
478  58 FIX
479  02  02
```

manpower costs

```
480  71 SBR   maintenance wage
481  00  00   and training
482  36  36
483  43 RCL
484  24  24
485  65  ×
486  43 RCL
487  29  29
488  65  ×
489  43 RCL
490  25  25
491  55  ÷
492  07  7   ← WHo
493  04  4
494  65  ×
495  43 RCL
496  12  12
497  95  =
498  42 STO   M'o = s·θ·AHR·Q/WHo
499  38  38
500  71 SBR
501  00  00
502  36  36
```

$C_S = (\bar{s} + s'L)\cdot UC$

```
503  43 RCL
504  34  34
505  85  +
506  43 RCL
507  07  07
508  65  ×
509  43 RCL
510  03  03
511  95  =
512  65  ×
513  43 RCL
514  08  08
515  71 SBR
516  00  00
517  21  21   Hardware
```

$C_6 = STE(1 + SOM(r_1)\tilde{S})(1 + mL) \cdot N$

```
518  43 RCL
519  30  30
520  65  ×
521  53  (
522  01  1
523  85  +
524  43 RCL
525  05  05
526  69 OP
527  10  10
528  65  ×
529  01  1   ← S̃
530  93  .
531  00  0
532  54  )
533  65  ×
534  53  (
535  01  1
536  85  +
537  93  .   ← m
538  01  1
539  02  2
540  65  ×
541  43 RCL
542  03  03
543  54  )
544  71 SBR   support and
545  00  00   test equipment
546  21  21
```

$C_7 = \tilde{\lambda} L (r_2 COD + r_1 RP) \cdot N$

```
547  43 RCL
548  36  36
549  65  ×
550  43 RCL
551  03  03
552  65  ×
553  53  (
554  43 RCL
555  09  09
556  65  ×
557  43 RCL
558  31  31
559  85  +
560  43 RCL
561  05  05
562  65  ×
563  43 RCL
564  32  32
565  54  )
566  71 SBR
567  00  00   repair
568  21  21
```

$C_8 = IEC\,n + IMC\,n\,L(1 + PP(r_1 + r_2))$

```
569  93  .   ← IEC
570  04  4
571  05  5
572  85  +
573  93  .   ← IMC
574  02  2
575  03  3
576  65  ×
577  43 RCL
578  03  03
579  65  ×
580  53  (
581  01  1
582  85  +
583  01  1   ← PP
584  93  .
585  00  0
586  65  ×
587  43 RCL
588  39  39
589  54  )
590  95  =
591  65  ×
592  43 RCL
593  11  11
594  71 SBR   item entry and
595  00  00   management
596  24  24
```

$C_9 = BOC(1 + r_1 n \tilde{D})$

```
597  69 OP
598  31  31
599  43 RCL
600  33  33
601  65  ×
602  53  (
603  01  1
604  85  +
605  43 RCL
606  05  05
607  65  ×
608  43 RCL
609  11  11
610  65  ×
611  01  1   ← D̃
612  93  .
613  00  0
614  54  )
615  71 SBR
616  00  00   Documentation
617  24  24
```

Print System Life Cycle Cost

```
618   98 ADV
619   43 RCL
620   37  37
621   99 PRT
622   98 ADV
623   22 INV
624   58 FIX
625   92 RTN
626   00  0
627   00  0
628   00  0
629   00  0
630   00  0
631   00  0
632   00  0
633   00  0
634   00  0
635   00  0
636   00  0
637   00  0
638   00  0
639   00  0
```

APPENDIX B:

LOWEST REMOVABLE ASSEMBLY

MODEL PROGRAM LISTING

PRINT and SUM to LCC

```
000  65  ×
001  43  RCL
002  37   37
003  95  =     LCC = LCC + N·Cj
004  44  SUM   if j ≤ 6 (enter at 000)
005  02   02
006  72  ST*   LCC = LCC + Cj
007  01   01   if j ≥ 7 (enter at 003)
008  87  IFF
009  40  IND   store Cj in Rj  j ≥ 2
010  01   01
011  00   00   if flag j is set
012  15   15   do not print Cj
013  69  OP
014  06   06
015  69  OP
016  20   20
017  69  OP
018  21   21
019  73  RC*
020  00   00   load op. code
021  69  OP    for next label
022  04   04
023  92  RTN
```

x = y·s·λ

```
024  65  ×
025  43  RCL
026  32   32   used
027  65  ×     three
028  43  RCL   times
029  29   29
030  95  =
031  42  STO
032  09   09
033  92  RTN
```

K(t)

```
034  29  CP
035  71  SBR
036  00   00
037  24   24   x = s·λ·t
038  75  -
039  43  RCL
040  04   04
041  67  EQ    if S=0
042  00   00   then K = e^-x
043  57   57   otherwise ↓
044  95  =
045  55  ÷
046  43  RCL
047  09   09
048  34  √x
049  95  =
050  36  PGM
051  14   14
052  11   A
053  36  PGM
054  14   14   K = Q((x-s)/√x)
055  12   B
056  92  RTN
```

if S=0

```
057  95  =
058  43  RCL
059  09   09
060  94  +/-
061  22  INV   K = e^-x
062  23  LNX
063  92  RTN
```

S(t,K)

```
064  71  SBR
065  00   00
066  24   24   x = s·λ·t
067  94  +/-
068  22  INV
069  23  LNX
070  32  X:T
071  43  RCL
072  07   07
073  22  INV   if e^-x ≥ K then
074  77  GE    S=0, otherwise ↓
075  01   01
076  37   37
```

```
077   75   -
078   01   1
079   95   =
080   33  X²
081   35  1/X
082   23  LNX
083   34  √X
084   42  STO
085   02   02
086   75   -
087   53   (
088   02   2
089   93   .
090   05   5
091   85   +
092   93   .
093   08   8
094   65   ×
095   43  RCL
096   02   02
097   54   )
098   55   ÷
099   53   (
100   01   1
101   85   +
102   01   1
103   93   .
104   04   4
105   65   ×
106   43  RCL
107   02   02
108   85   +
109   93   .
110   01   1
111   09   9
112   65   ×
113   43  RCL
114   02   02
115   33  X²
116   54   )
117   95   =
118   65   ×
119   43  RCL
120   09   09
121   34  √X
122   85   +
123   43  RCL
124   09   09
125   95   =
```

$h = \sqrt{\log\left(\frac{1}{1-K}\right)^2}$

$Z = h - \frac{2.5 + .8h}{1 + 1.4h + .19h^2}$

$h = x + Z\sqrt{x}$

$\lceil x \rceil$

```
126   32  X:T
127   00   0
128   77   GE
129   01   01
130   36   36
131   32  X:T
132   85   +
133   01   1
134   95   =
135   59  INT
136   92  RTN
137   00   0
138   92  RTN
```

$\lceil x \rceil = \begin{cases} 0 & x \le 0 \\ \text{INT}(x)+1 & x > 0 \end{cases}$

end of S(t,K)

```
139   76  LBL   BEGIN EXECUTION
140   11   A
141   43  RCL
142   30   30
143   65   ×
144   43  RCL
145   12   12
146   65   ×
147   43  RCL
148   13   13
149   65   ×
150   43  RCL
151   31   31
152   55   ÷
153   43  RCL
154   14   14
155   95   =
156   42  STO
157   29   29
158   43  RCL
159   35   35
160   42  STO
161   07   07
162   43  RCL
163   15   15
164   65   ×
165   43  RCL
166   33   33
167   85   +
168   43  RCL
169   16   16
170   65   ×
171   43  RCL
172   34   34
173   95   =
174   42  STO
175   28   28
```

$\lambda = \beta \cdot Q \cdot \delta \cdot \text{AHR}/\text{MTBF}$

$K = K_i$

$t = r_1 \text{LRT} + r_2 D$

```
176  71 SBR
177  00  00
178  64  64   S = S(t, K_i)
179  42 STO
180  04  04
181  43 RCL
182  28  28
183  71 SBR
184  00  00
185  34  34
186  42 STO   Save K(t)
187  28  28

188  43 RCL   if r_2 = 0
189  16  16   then B = 0
190  67  EQ   otherwise ↓
191  02  02
192  32  32

193  43 RCL
194  36  36
195  71 SBR
196  00  00   K(XD)
197  34  34
198  42 STO
199  10  10
200  75  -
201  43 RCL
202  35  35
203  95  =
204  55  ÷
205  53  (
206  43 RCL
207  10  10
208  75  -
209  43 RCL
210  28  28
211  54  )
212  95  =
213  42 STO   b = (K_i - K(XD)) / (K(D) - K(XD))
214  07  07

215  43 RCL
216  37  37
217  65  ×
218  43 RCL
219  38  38
220  55  ÷
221  02  2   ← d
222  71 SBR
223  00  00
224  64  64   B = S(N·DRT/d, b)

225  44 SUM   save B as B·K(t)
226  28  28
227  65  ×
228  02  2   ← d
229  55  ÷
230  43 RCL
231  37  37   B̄ = B·d/N

232  85  +
233  43 RCL
234  30  30
235  65  ×
236  43 RCL
237  12  12
238  95  =
239  44 SUM
240  04  04   S = S + B̄ + q·R

Replenishment Spares

241  43 RCL
242  29  29
243  65  ×
244  43 RCL
245  34  34
246  65  ×
247  02  2   ← h
248  95  =
249  42 STO   λ̄ = λ·D·h
250  06  06
251  65  ×
252  53  (
253  01  1
254  75  -
255  53  (
256  43 RCL
257  15  15
258  85  +
259  43 RCL
260  16  16
261  54  )
262  42 STO   r̄ = r_1 + r_2
263  07  07
264  65  ×
265  43 RCL   ← 1-COND
266  40  40
267  54  )
268  95  =
269  42 STO   S' = λ̄(1 - r̄(1-COND))
270  05  05
```

$UC = UC_e \left[\frac{N(S+S')}{\ell} \right]^{\log ARATE/\log 2}$

```
271   85   +
272   43 RCL
273   04   04
274   95   =
275   65   ×
276   43 RCL
277   37   37
278   55   ÷
279   43 RCL
280   39   39
281   95   =
282   45 YX
283   43 RCL   ← log ARATE/log 2
284   41   41
285   65   ×
286   43 RCL
287   17   17
288   95   =
289   42 STO
290   59   59
```

Initialize for printing

```
291   58 FIX
292   02   02
293   02   2
294   42 STO   indirect register
295   01   01  for $C_j$
296   05   5
297   01   1
298   42 STO   indirect register
299   00   00  for labbles
300   71 SBR
301   00   00  place op code for
302   19   19  $C_2$ in print register
```

$M'_m = s\lambda(WTRR + r_i\ WTTR)/U \cdot WH_m$

```
303   43 RCL
304   18   18
305   85   +
306   43 RCL
307   15   15
308   65   ×
309   43 RCL
310   19   19
311   95   =
312   55   ÷
313   05   5
314   03   3   ← U·WH_m
315   71 SBR
316   00   00
317   24   24
```

$A(m') = \lceil m' - \min(m', AN) \rceil$

```
318   32 X:T
319   43 RCL
320   09   09
321   75   -
322   43 RCL
323   44   44
324   22 INV
325   77   GE
326   03   03
327   29   29
328   32 X:T
329   71 SBR
330   01   01
331   25   25
332   42 STO
333   03   03
```

$C_2 = (m'/s \cdot BG + A(m')(BN - BG))L \cdot N$

```
334   65   ×
335   53   (
336   43 RCL
337   45   45
338   75   -
339   43 RCL
340   46   46
341   54   )
342   85   +
343   43 RCL
344   09   09
345   55   ÷
346   43 RCL
347   32   32
348   65   ×
349   43 RCL
350   46   46
351   95   =
352   65   ×
353   43 RCL
354   47   47
355   71 SBR
356   00   00  print wage
357   00   00
```

$C_3 = (\lceil m' \rceil (TF1 + r_1 TR) + A(m')TA)(1+TOR \cdot L) \cdot N$

```
358  43 RCL
359  09  09
360  71 SBR
361  01  01  ← ⌈m'⌉
362  26  26
363  65  ×
364  53  (
365  43 RCL
366  20  20
367  85  +
368  43 RCL
369  15  15
370  65  ×
371  43 RCL
372  21  21
373  54  )
374  85  +
375  43 RCL
376  03  03
377  65  ×
378  43 RCL
379  48  48
380  95  =
381  65  ×
382  43 RCL  ← 1+TOR·L
383  49  49
384  71 SBR
385  00  00  Print Training
386  00  00
```

$C_4 = (S + S' \cdot L) \cdot WC \cdot N$

```
387  43 RCL
388  04  04
389  85  +
390  43 RCL
391  05  05
392  65  ×
393  43 RCL
394  47  47
395  95  =
396  65  ×
397  43 RCL
398  59  59
399  71 SBR
400  00  00  Print Hardware
401  00  00
```

$C_5 = (STE_{avg} + r_1 STE_{rpr})(1 + mL) \cdot N$

```
402  43 RCL
403  22  22
404  85  +
405  43 RCL
406  15  15
407  65  ×
408  43 RCL
409  23  23
410  95  =
411  65  ×
412  43 RCL
413  50  50  ← 1+mL
414  71 SBR
415  00  00  Print Support and
416  00  00  Test Equipment
```

$C_6 = \bar{\lambda} \cdot L (r_1 WC/C + r_2 COD)$

```
417  43 RCL
418  15  15
419  65  ×
420  43 RCL
421  59  59
422  55  ÷
423  43 RCL
424  24  24
425  85  +
426  43 RCL
427  16  16
428  65  ×
429  43 RCL
430  43  43
431  95  =
432  65  ×
433  43 RCL
434  06  06
435  65  ×
436  43 RCL
437  47  47
438  71 SBR
439  00  00  Print Repair
440  00  00
```

$C_7 = (1 + \bar{\tau}\varepsilon)(IEC + IMC \cdot L)$

```
441   01   1
442   85   +
443   43 RCL
444   07   07
445   65   ×
446   43 RCL
447   25   25
448   95   =
449   65   ×
450   43 RCL
451   42   42   ← IEC + IMC·L.
452   71 SBR
453   00   00   Print Item Entry
454   03   03   and Management
```

$C_8 = P_f + r_1 P_r$

```
455   43 RCL
456   26   26
457   85   +
458   43 RCL
459   15   15
460   65   ×
461   43 RCL
462   27   27
463   95   =
464   71 SBR
465   00   00   Print Documentation
466   03   03
```

Print Life-Cycle Cost

```
467   98 ADV
468   43 RCL
469   02   02
470   69 DP
471   06   06
```

```
472   00   0
473   42 STO   set TC_0 = 0
474   03   03
475   22 INV
476   58 FIX
477   92 RTN
```

APPENDIX C:

SYSTEM AGGREGATION MODEL

PROGRAM LISTING

PRINT, STORE, SUM to LCC

```
000   76 LBL
001   99 PRT
002   85  +
003   73 RC*
004   00  00   Σ_i C_i,j
005   65  ×
006   43 RCL
007   44  44
008   95  =
009   72 ST*   output
010   02  02   register
011   69 □P
012   20  20
013   69 □P
014   22  22
015   87 IFF   if flag j is
016   40 IND   set do not
017   03  03   print C_j
018   00  00
019   22  22
020   69 □P
021   06  06
022   44 SUM   sum to LCC
023   40  40
024   73 RC*
025   01  01
026   69 □P    store op code
027   04  04   for next lable
028   69 □P    in print reg.
029   21  21
030   69 □P
031   23  23
032   92 RTN
```

PERSONNEL

```
033   73 RC*
034   00  00
035   69 □P
036   20  20
037   42 ST□   M'
038   45  45
039   32 X↕T
040   43 RCL
041   45  45
042   75  -
043   73 RC*
044   00  00
045   69 □P
046   20  20
047   22 INV
048   77  GE
049   00  00
050   52  52
051   32 X↕T
052   95  =
053   32 X↕T
054   00  0
055   77  GE
056   00  00
057   63  63
058   32 X↕T
059   59 INT
060   85  +
061   01  1
062   95  =
063   42 ST□   A(M') = ⌈M' - min(M', AD)⌉
064   46  46
```

Wage = (m'/s·BG + A(m')(BN-BG)·L·N

```
065  65  ×
066  53  (
067  73  RC*
068  00   00
069  69  DP
070  20   20
071  75  -
072  43  RCL
073  07   07
074  54  )
075  85  +
076  43  RCL
077  45   45
078  55  ÷
079  43  RCL
080  05   05
081  65  ×
082  43  RCL
083  07   07
084  95  =
085  65  ×
086  43  RCL
087  09   09
088  65  ×
089  43  RCL
090  08   08
091  95  =
092  71  SBR
093  00   00   print Wage
094  15   15
```

Trn = (A(m')TA + [m']TC)(1+TDR·L)·N

```
095  43  RCL
096  46   46
097  65  ×
098  73  RC*
099  00   00
100  69  DP
101  20   20
102  85  +
103  53  (
104  43  RCL
105  45   45
106  32  X:T
107  43  RCL
108  45   45
109  59  INT
110  67  EQ
111  01   01
112  15   15
113  85  +
114  01   1
115  54  )
116  65  ×
117  73  RC*
118  00   00
119  69  DP
120  20   20
121  95  =
122  65  ×
123  43  RCL
124  29   29
125  65  ×
126  43  RCL
127  08   08
128  95  =
129  71  SBR
130  00   00   print Training
131  15   15
132  92  RTN
```

end of subroutine PERSONNEL

```
AGGREGATION
133   76 LBL
134   12  B
135   94 +/-   ← -QIPA_i
136   76 LBL
137   11  A
138   42 STO
139   45  45   ← QIPA_i
140   44 SUM
141   41  41
142   55  ÷
143   43 RCL
144   14  14
145   95  =
146   44 SUM   Σ QIPA_i / MTBF_i
147   42  42
148   43 RCL
149   18  18
150   85  +
151   43 RCL
152   15  15
153   65  ×
154   43 RCL
155   19  19
156   95  =
157   65  ×
158   43 RCL
159   45  45
160   95  =
161   44 SUM   Σ MTRR_i + r_s,i MTTR_i
162   43  43
163   43 RCL
164   20  20
165   85  +
166   43 RCL
167   15  15
168   65  ×
169   43 RCL
170   21  21
171   95  =
172   42 STO   TC_m = TS_i + r_s,i TC_mci)
173   02  02
174   43 RCL
175   45  45
176   55  ÷
177   43 RCL
178   12  12
179   95  =
180   42 STO   R_i = QIPA_i / g_i
181   46  46
```

initialize indirect registers

```
182   03   3
183   42 STO   c_ji ind reg
184   00   00
185   03   3
186   09   9
187   42 STO   Σ_i c_i,j ind reg
188   01   01
```

sum in accumulation registers

```
189   73 RC*
190   00   00
191   65   ×     for j = 9-1
192   43 RCL
193   46   46    c_j = c_j + R_i c_i,j
194   95   =
195   74 SM*
196   01   01
197   69 DP
198   31   31
199   97 DSZ
200   00   00
201   01   01
202   89   89
```

```
203   43 RCL
204   11   11    print LRA
205   69 DP      identifier
206   04   04
207   43 RCL
208   45   45
209   69 DP
210   06   06
211   92 RTN
```

end of AGGREGATION

SYSTEM COSTS

```
212  76 LBL
213  13  C
214  58 FIX
215  02  02
216  43 RCL
217  12  12
218  65  ×
219  43 RCL
220  06  06
221  95  =
222  42 STO
223  44  44
224  65  ×
225  53  (
226  43 RCL
227  13  13
228  55  ÷
229  05  5
230  03  3
231  85  +
232  43 RCL
233  39  39
234  54  )
235  95  =
236  42 STO
237  13  13
238  43 RCL
239  32  32
240  65  ×
241  43 RCL
242  44  44
243  95  =
244  44 SUM
245  17  17
246  43 RCL
247  05  05
248  65  ×
249  43 RCL
250  10  10
251  55  ÷
252  07  7
253  04  4
254  65  ×
255  43 RCL
256  44  44
257  95  =
258  49 PRD
259  18  18
260  43 RCL
261  33  33
262  65  ×
263  43 RCL
264  44  44
265  95  =
266  44 SUM
267  22  22
```

$n = q \cdot Q$

$\leftarrow U \cdot WH_m$

$m'_m = n \cdot SM / U \cdot WH_m + \sum_i m'_{m(i)}$

$TC_m = TS + n\sum_i TC_{m(i)}$

$\leftarrow WH_o$

$m'_o = s \cdot AHR \cdot n \cdot \theta / WH_o$

$TC_o = TS_o + n\sum TC_o$

initialize indirect registers

```
268  00   0
269  42 STO
270  40  40   LCC
271  42 STO   ind. reg. for print/no print flags
272  03  03
273  01  1
274  03  3
275  42 STO   ind. reg. for o and
276  00  00   m subscripted variables
277  04  4
278  07  7
279  42 STO   ind reg. for labels
280  01  01
281  71 SBR   store op. code for
282  00  00   first label in print register
283  24  24
```

C_1 = Maintenance Wage
C_2 = Maintenance Training

```
284  71 SBR
285  00  00   call subroutine PERSONNEL
286  33  33
```

C_3 = Operator Wage
C_4 = Operator Training

```
287  71 SBR
288  00  00   call subroutine PERSONNEL
289  33  33
```

initial initialize registers

```
290  04  4
291  42 STO   indirect reg. for
292  02  02   output costs
293  03  3
294  04  4    ind. reg. for
295  42 STO
296  00  00   Σ C_i,j
```

$C_5 = N \cdot n \cdot PT_e \left(\frac{N \cdot n}{i}\right)^{\log RRATE/\log 2} + n \sum_i HRDW_i$

```
297   43 RCL
298   08  08
299   65  ×
300   43 RCL
301   44  44
302   55  ÷
303   43 RCL
304   24  24
305   95  =
306   45 Y^x
307   43 RCL   ← log RRATE/log 2
308   25  25
309   65  ×
310   43 RCL
311   23  23
312   65  ×
313   43 RCL
314   08  08
315   65  ×
316   43 RCL
317   44  44
318   71 SBR
319   99 PRT   Print Hardware
```

$C_6 = N \cdot STE \cdot (1+mL) + n \sum_i STE_i$

```
320   43 RCL
321   08  08
322   65  ×
323   43 RCL
324   27  27
325   65  ×
326   43 RCL
327   28  28
328   71 SBR
329   99 PRT   Print Support & Test Equipment
```

$C_7 = n \sum_i RPR_i$

```
330   71 SBR
331   00  00
332   03  03   Print Repair
```

$C_8 = n \sum_i IEMC_i$

```
333   71 SBR
334   00  00
335   03  03   Print Item Entry and management
```

$C_9 = DOC_{sys} + n \sum_i DOC_i$

```
336   69 OP
337   33  33   Flag 8 will suppress
338   43 RCL   printing C8 and C9
339   26  26
340   71 SBR
341   99 PRT   Print Documentation
```

Make output compatible with Aggregation input

```
342   43 RCL
343   13  13
344   42 STO   STO M'm
345   09  09
346   43 RCL
347   17  17
348   42 STO   STO TCm
349   20  20
350   43 RCL
351   22  22
352   42 STO   STO TC0
353   03  03
354   00  0
355   42 STO   set r1=0
356   15  15
357   43 RCL
358   43  43
359   55  ÷
360   43 RCL
361   41  41
362   95  =
363   42 STO   MTTRS = Σ MTTRi / Σ QIPAi
364   18  18
365   43 RCL
366   42  42
367   35 1/x
368   42 STO   MTBF = (Σ MTBFi)^-1
369   14  14
```

Print Life Cycle Cost

```
370   98 ADV
371   43 RCL
372   40  40
373   71 SBR
374   00  00
375   20  20
376   22 INV
377   58 FIX
378   92 RTN
```

Print MTBF and MTTR

```
379   76 LBL
380   14  D
381   58 FIX
382   02  02
383   98 ADV
384   43 RCL
385   14  14
386   71 SBR  ← MTBF
387   00  00
388   20  20
389   43 RCL
390   18  18
391   71 SBR  ← MTTR
392   00  00
393   20  20
394   22 INV
395   58 FIX
396   92 RTN
```

APPENDIX D:

SYSTEM CONFIDENCE LEVEL

PROGRAM LISTING

```
069   76 LBL
070   13  C
071   00  0   ← divide out
072   75  -
073   76 LBL
074   12  B
075   01  1   ← prod K
076   95  =
077   42 STO
078   42  42
```

```
079   29 CP
080   43 RCL   if r1 = 1
081   15  15   (local repair)
082   22 INV   K already
083   67  EQ   computed B=0
084   01  01
085   29  29   K(L) = K(LAST)
```

compute confidence level at depot

```
086   43 RCL
087   41  41
088   65  ×
089   43 RCL
090   29  29
091   95  =
092   42 STO   x = λy
093   00  00
094   75  -
095   43 RCL
096   28  28
097   59 INT
098   67  EQ   if B=0
099   01  01   b = e^-x
100   59  59
101   95  =
102   55  ÷
103   43 RCL
104   00  00
105   34 Γx
106   95  =
107   36 PGM
108   14  14
109   11  A
110   36 PGM
111   14  14   b = Q((x-B)/√x)
112   12  B
```

compute achieved confidence level

```
113   65  ×
114   53  (
115   43 RCL
116   28  28
117   22 INV
118   59 INT
119   75  -
120   43 RCL
121   10  10
122   54  )
123   85  +
124   43 RCL
125   10  10
126   95  =
127   42 STO
128   28  38   K = b(K(D) - K(XD)) + K(XD)
```

initialize printing register

```
129   43 RCL
130   11  11
131   69 OP
132   04  04
133   58 FIX
134   02  02
```

```
135   43 RCL
136   28  28
137   45 Y^x
138   43 RCL
139   42  42
140   95  =
141   49 PRD   if R_qz = -1 then
142   40  40   divide out of K
143   45 Y^x   and print -K x 100
144   43 RCL
145   42  42
146   65  ×
147   43 RCL   else prod K
148   42  42   and print K x 100
149   65  ×
150   01  1
151   00  0
152   00  0
153   95  =
154   69 OP
155   06  06
156   22 INV
157   58 FIX
158   92 RTN
```

```
000   76  LBL  BEGIN EXECUTION
001   11   A
002   43  RCL
003   32   32
004   65   ×
005   43  RCL
006   37   37
007   65   ×
008   43  RCL
009   38   38
010   55   ÷
011   02   2   ← d
012   95   =
013   42  STO  Y= S.N.DRT/d
014   41   41
015   01   1
016   42  STO  K=1
017   40   40
```

Print Initialization Heading

```
018   01   1
019   05   5
020   03   3
021   02   2
022   03   3
023   01   1
024   02   2
025   01   1
026   02   2
027   04   4
028   69  ΣP   "CONFI"
029   01   01
030   01   1
031   06   6
032   01   1
033   07   7
034   03   3
035   01   1
036   01   1
037   05   5
038   01   1
039   07   7
040   69  ΣP   "DENCE"
041   02   02
042   02   2
043   07   7
044   01   1
045   07   7
046   04   4
047   02   2
048   01   1
049   07   7
050   69  ΣP   ",LEVE"
051   03   03
052   02   2
053   07   7
054   00   0
055   00   0
056   05   5
057   05   5
058   06   6
059   01   1
060   05   5
061   06   6
062   69  ΣP   "L, (%)"
063   04   04
064   98  ADV
065   69  ΣP
066   05   05
067   98  ADV
068   92  RTN
```

```
# B=0
159   95   =
160   43 RCL
161   00   00
162   94 +/-
163   22 INV
164   23 LNX      b=e^-x
165   61 GTO
166   01   01
167   13   13
```

```
Print System Confidence Level
168   76 LBL
169   14   D
170   69 OP
171   00   00
172   03   3
173   06   6
174   04   4
175   05   5
176   03   3
177   06   6
178   69 OP
179   02   02     "vvSYS"
180   03   3
181   07   7
182   01   1
183   07   7
184   03   3
185   00   0
186   00   0
187   00   0
188   00   0
189   00   0
190   69 OP       "TEMvv"
191   03   03
192   98 ADV
193   69 OP
194   05   05
195   58 FIX
196   02   02
197   43 RCL
198   40   40
199   65   ×
200   01   1
201   00   0
202   00   0
203   95   =
204   99 PRT      Print K×100
205   98 ADV
206   22 INV
207   58 FIX
208   92 RTN
```